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(54) ELECTRICAL PROTECTIVE ARRANGEMENT FOR A RECIPROCATING COMPRESSOR

(71) We, DANFOSS A/S, a Danish Company of, DK-6430 Nordborg, Denmark, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an electrical protective arrangement for a reciprocating compressor having a plurality of delivery chambers into which compressed gas is delivered by associated piston and cylinder arrangements respectively. Such a protective arrangement is particularly useful in refrigerant compressors.

If the outlet or delivery valve of a cylinder of a refrigerant compressor breaks down, cold inlet gas is not, as is normal, introduced into the cylinder during a suction stroke, but the previously-compressed hot gas returns to the cylinder and is compressed again during the subsequent compression stroke, further heat then being generated. Since the entire mechanical power is converted into heat when the piston reciprocates and no cooling takes place by the inflow of cool inlet gas, there occurs an increase in temperature which, after a short time, leads to seizing up of the cylinder and thus to considerable damage to the compressor.

Various methods involving temperature-monitoring means have been tried for switching off the compressor before the above mentioned damage occurs. Considerable difficulties have been encountered, however, particularly if the compressor includes several cylinders and the delivery valve associated with only one cylinder breaks down.

Thus, it is known to fit a temperature-responsive sensor on the exterior of each cylinder. Because of the considerable mass of the cylinder and its connection with the other cooled cylinders, such a temperature-responsive sensor generally responds too late.

It is also known to fit a temperature-responsive sensor at the outlet or delivery pipe of the compressor. This sensor, however, had to respond to very small rises in temperature, since the temperature measured at the point in question was largely determined by the temperature of the compressed gas fed by the sound cylinders, the hotter gas from the defective cylinder being only a small proportion of the total gas delivered. Consequently, the defect could not be properly detected in this manner. Instead, it frequently happened that the temperature-responsive sensor responded to a slight rise in the ambient temperature.

According to the present invention an electrical protective arrangement for a reciprocating gas compressor having a plurality of gas delivery chambers into which compressed gas is delivered by associated piston and cylinder arrangements respectively, includes a plurality of temperature sensitive electrical resistor devices disposed, when the arrangement is in operation, in the respective gas delivery chambers for exposure there to compressed gas flowing therein, electric circuit means connecting the respective resistor devices in series with one another and with an electrical relay device which is arranged to control the supply of driving power to the compressor, the resistor devices having at normal gas temperatures in the respective delivery chambers a total series electrical resistance such as will maintain the relay device in an operative state such as to maintain the supply of driving power to the compressor, and each resistor device having a temperature-electrical resistance characteristic such that any one resistor device on reaching a predetermined danger temperature experiences a change in electrical resistance sufficient to cause a change in the current in the relay device, which change is sufficient to produce a change in the relay state whereby the supply of driving power to the compressor is switched off.

In such a protective arrangement each delivery valve chamber has associated therewith an electrical resistor device functioning as a temperature-responsive sensor. Since each temperature-responsive sensor is exposed to the compressed gas emerging from the associated cylinder, the temperature at the sensor rises considerably when a defect occurs. Thus, a

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considerable rise in temperature, e.g. 10—20°C, up to the temperature at which the compressor drive is to be switched off is possible. As the temperature sensor is fitted in the delivery valve chamber, it responds very rapidly. Consequently, rapid and reliable switching off of the compressor drive occurs when a delivery valve breaks down.

The protective arrangement is suitable for compressors having cylinders arranged in series, as well as for compressors having cylinders arranged in parallel. The cylinders can be arranged for example in the well-known V formation or star formation. If the cylinders are disposed in groups and each group has a common delivery valve chamber, it suffices to fit a temperature-responsive resistor device in each of these common delivery valve chambers.

A protective arrangement according to the present invention is particularly advantageous in that the resistor devices are connected in series and control a single electrical relay device.

The resistors are expediently positive temperature coefficient resistors (referred to later as PTC-resistors), the resistance of which increases with rising temperature. Resistors having a very steep characteristic curve are commercially available so that when a predetermined danger temperature is reached considerable changes in resistance occur which operate to cause the driving power for the compressor to be switched off. Moreover, a self-monitoring action occurs, since the relay device is held in its operative state by a predetermined steady current, and releases not only when a defect occurs, and the current through the resistor changes, but also when the supply voltage for the protective arrangement is lost.

It is desirable that the temperature-responsive resistor device should respond as rapidly as possible to changes in gas temperature so that the actual switching-off of the compressor driving power can take place immediately after the gas in a delivery chamber has reached the danger temperature. This can be facilitated by securing the resistor device to the metal parts of the wall of the delivery valve chamber by a supporting means made of a material of low thermal conductivity. With such an arrangement the supporting means ensures that the resistor device actually assumes a temperature approximating to that of the gas, i.e. it ensures that a substantial part of the heat derived from the gas is not passed to the cooler delivery valve chamber wall via another path.

In particular, the supporting means may consist of a tube having a closed end projecting through the wall of the chamber, the resistor device being disposed within the said closed end in good heat-conducting contact therewith. A closed tube of this kind separates the electrical resistor device from the compressor gas flow circuit, so that there is no risk of troublesome chemical reactions or of small pieces of material detached from the resistor being able to contaminate the said gas circuit. Since the tube may be of small wall-thickness, the flow of heat between the gas and the resistor can be virtually uninhibited; on the other hand, however, dissipation of heat along the thin wall of the tube to the delivery chamber wall is, for all practical purposes, prevented.

In this arrangement, the tube can be fitted in an externally screw-threaded bush which is screwed into the delivery chamber wall, and over at least a substantial part of the length of the bush the tube can be spaced radially from the inner surface of the bush. In this way a tube having appropriately low heat-conducting characteristics can be obtained, so that loss to the chamber wall can be minimised. Nevertheless, it is only necessary for the sensing resistor device to project a relatively short distance into the delivery valve chamber. It has been found that if the tube is properly insulated from the chamber wall, a distance of approximately 1 cm from the delivery chamber wall is sufficient (irrespective of the type of compressor and the size of delivery valve chamber) to ensure proper response of the resistor device. The arrangement described can therefore be generally used with compressors of a wide variety of size and type.

In a further embodiment, the supporting means consists of a glass plug extending through the chamber wall and in which are embedded a carrier for the resistor and the electric leads. Only one electric lead will suffice if the carrier can be used as the other lead.

The invention will now be described in more detail, by way of example, with reference to the accompanying drawing, in which:

Fig. 1 shows schematically a refrigerant compressor having four cylinders arranged in parallel and incorporating a protective arrangement according to the present invention;

Fig. 2 is a schematic cross-section through the upper part of two compressor cylinders having a common delivery valve chamber, showing a first form of electrical resistor device suitable for use as a temperature-responsive sensor in a compressor protective arrangement according to the present invention; and

Fig. 3 shows, partly in side elevation and partly in section, a second form of electrical resistor device suitable for use as a temperature-responsive sensor for use in a compressor protective arrangement according to the present invention.

Fig. 1 shows schematically an electric motor 1 which drives multi-cylinder compressor 4 through a shaft 2 and a coupling 3. The compressor has four cylinders 5, a common suction or inlet pipe 6, and a common delivery or outlet pipe 7.

Delivery valve chambers 8 are associated with the respective cylinders 5, and these

chambers are connected to each other and to the delivery pipe 7 through lengths of piping. Each delivery valve chamber 8 contains a PTC-resistor 9. These resistors are series-connected with one another and with an electrical relay 10. The relay controls a two-pole switch 11 connected in the supply circuit of the motor 1. The motor 1 and the protective circuit comprising the devices 9, 10 are supplied from a common supply voltage source 12 by way of a main switch 13. If a delivery valve associated with one of the cylinders 5 breaks down, the gas temperature in the associated delivery chamber rises rapidly from the normal operating level which, depending upon conditions, may be between 100 and 140°C. The PTC-resistors 9 are so rated that when a rise in temperature of 20°C occurs, an increase in resistance takes place such that the current in the relay 10 drops below the relay holding current. Consequently, the switch 11 opens and the driving motor 1 is stopped before there is any risk of the associated piston seizing up in its cylinder. Since such a response of the relay 10 indicates a particular defect, namely breakage of a delivery valve, the appropriate repair can be rapidly carried out.

In the arrangement shown in Fig. 2, two cylinders 14 and 15 with their associated pistons 16 and 17, driven in opposite directions, form a cylinder group having a common delivery valve chamber 18. This chamber is closed by a cover-plate 19 which is mounted on a valve plate 20, and is connected to a gas delivery pipe 21. Openings 22 and 23 in the valve plate 20 inter-connect the chamber 18 with each cylinder 14, and these openings are covered by small spring-loaded delivery-valve plates 24 and 25 respectively.

A screwed insert 26, consisting of an outer metal bush 27 and a glass lead-through plug 28, is screwed into the wall of the cover plate 19. Embeded in the glass lead-through plug is a support 29 for a PPTC-resistor element 30 and a lead 29a. The support 29 acts as a second lead. The glass of the lead-through plug 28 constitutes a heat-insulation which prevents heat supplied to the resistor device 30 from passing to the cover plate 19. Since the resistor device 30 is directly exposed to the temperature of the compressed gas emerging from the cylinders, it can very rapidly detect an increase in temperature arising from a breakage of one of the delivery valves 24 or 25.

The suction valves have not been shown in the drawings of these embodiments. They are of the usual design and are disposed, for example, in a plane other than those of the cross-sections. The two-cylinder group shown in Fig. 2 can for example replace each of the cylinders 5 in Fig. 1.

Referring to Fig. 3, a screw-threaded bush 33 is screwed into a wall 31 of a delivery valve chamber 32. The bush has an opening 34 which diverges towards its lower end and in which a thin stainless-steel tube 35 is inserted in such manner that, over a substantial part of the bush 33, there is a gap 36 between the bush and the tube. The steel tube has a closed end 37 and a wall-thickness of approximately 0.1 mm. At the closed end of the tube is a PTC-resistor element 38 which is secured to the closed end 37 of the tube by means of a synthetic resin filler. Two leads 39 run from the resistor element 38 to a terminal tab 40, to which the external leads can also be connected. A rubber sealing bush 42 and a lead-out sleeve 43 are held in position by a cap screw 41.

Through the thin wall of the closed end 37 of the tube, the resistor element 38 very rapidly assumes the temperature of the gas in the delivery valve chamber 32. The long cylindrical wall of the tube 35 however prevents any substantial dissipation of heat to the wall 31 of the delivery chamber.

It will be appreciated that the arrangements described above enable a compressor to be rapidly and reliably switched off before damage can occur after failure of a delivery valve.

WHAT WE CLAIM IS:—

1. An electrical protective arrangement for a reciprocating gas compressor having a plurality of gas delivery chambers into which compressed gas is delivered by associated piston and cylinder arrangements respectively,

there arrangement including a plurality of temperature sensitive electrical resistor devices disposed, when the arrangement is in operation, in the respective gas delivery chambers for exposure there to compressed gas flowing therein,

electric circuit means connecting the respective resistor devices in series with one another and with an electrical relay device which is arranged to control the supply of driving power to the compressor,

the resistor devices having at normal gas temperatures in the respective delivery chambers a total series electrical resistance such as will maintain the relay device in an operative state such as to maintain the supply of driving power to the compressor, and

each resistor device having a temperature-electrical resistance characteristic such that any one resistor device on reaching a predetermined danger temperature experiences a change in electrical resistance sufficient to cause a change in the current in the relay device, which change is sufficient to produce a change in the relay state whereby the supply of driving power to the compressor is switched off.

2. An electrical protective arrangement according to Claim 1, wherein each resistor device is located, when in operation, in a gas

delivery chamber which serves more than one piston and cylinder arrangement.

3. An electrical protective arrangement according to Claim 1, or Claim 2, wherein each resistor device comprises a PTC resistor device.

4. An electrical protective arrangement according to Claim 3, wherein each PTC resistor device experiences a substantial increase in electrical resistance at the said predetermined danger temperature.

5. An electrical protective arrangement according to any preceding Claim, wherein each resistor device is supported by electrical leads which pass through a plug of a poor heat transmitting material, the plug being secured in a metal bush, which in turn is secured in a wall of the associated delivery chamber.

6. An electrical protective arrangement according to any one of the Claims 1 to 4, wherein each resistor device is secured in the closed end of a thin metal-walled tube in good heat transmitting relationship therewith, the tube being itself secured in an externally screw-threaded bush which is screwed into a wall of the associated delivery chamber, and the tube being closely fitting in the said bush at a small part only of the axial length of the bush.

7. An electrical protective arrangement according to Claim 6, wherein the said length of the bush lies mostly externally of the outer surface of the said wall of the delivery chamber.

8. A compressor having an electrical protective arrangement according to any preceding Claim.

9. An electrical protective arrangement according to any one of the Claims 1 to 7, substantially as hereinbefore described with reference to and as illustrated in the accompanying drawing.

10. A compressor according to Claim 8, substantially as hereinbefore described with reference to and as illustrated in the accompanying drawing.

ABEL & IMRAY,
Chartered Patent Agents,
Northumberland House,
303—306 High Holborn,
London WC1V 7LH.

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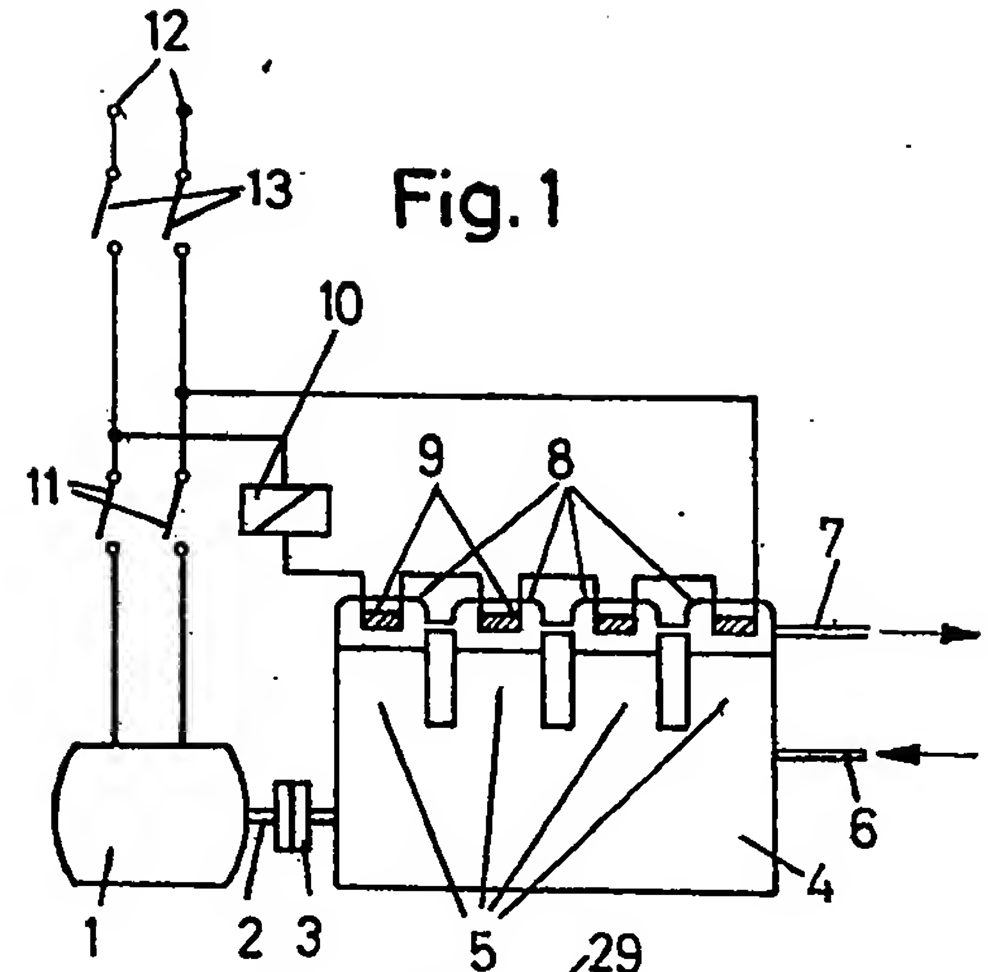
Fig. 1



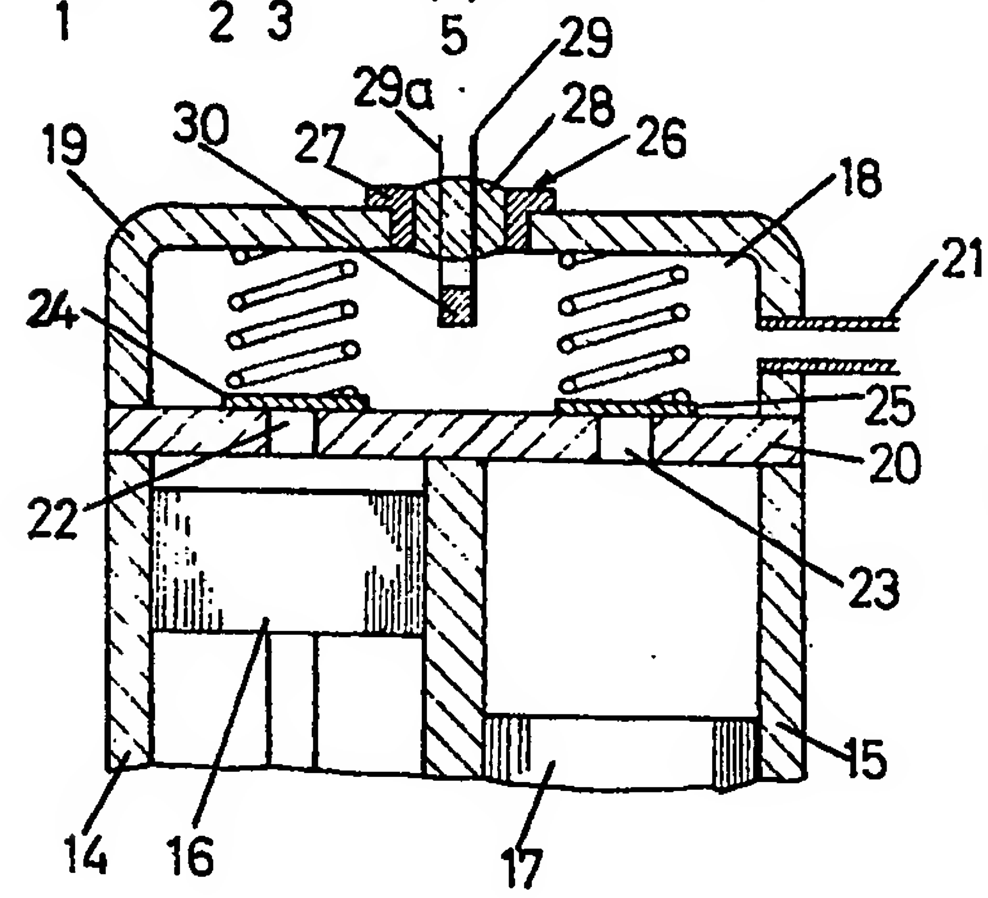


Fig. 2

Fig. 3